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Energy Feedback Systems: Evaluation of Meta-studies on energy savings through feedback

Energy Efficiency Directive Articles 9-11 on Feedback, Billing and Consumer information

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Energy Feedback Systems: Evaluation of Meta-studies on energy savings through feedback
The Energy Efficiency Directive, in its Articles 9 to 11 focuses on the availability of accurate, up to date information to be provided to final energy consumers in a cost-effective way. The present study proposes a literature review on existing studies regarding energy feedback systems, having in consideration the type of feedback, its duration, the geographical area where these have been performed and the correlation from these with the type of energy carrier being used by the final consumers. The main objective of this report is to provide evidence of the effectiveness of direct and indirect feedback and what the potential savings depending on type of media chosen for the interaction with the costumers may reach.

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1. Introduction

The present study has been conducted by the European Commission's Joint Research Centre on behalf of DG ENER with the purpose to understand the potential of different energy feedback systems and how these can contribute in achieving energy savings in a consistent way.

Articles 9 and 10 of the Energy Efficiency Directive (EED) focus on providing accurate and regular metering information for final energy consumers with the roll-out of smart metering systems being of considerable importance to this effect. The focus on providing reliable, timely and accurate information to consumers is considered to be crucial so that these consumers become more aware of their consumption patterns and can act accordingly in order to manage their behaviour in terms of achieving energy savings with this information at hand. The awareness raising can be achieved through different means of communication between energy companies and the final consumer.

This report pulls together findings from scientific meta-studies that assess energy feedback projects and analyses the outcomes of such studies, having in consideration the specificities of each study in terms of geographical area of the study, type of energy carrier (electricity, gas etc.), the year of the study, sample size, type and frequency of the feedback and the medium used for the interaction between the energy company and the final energy consumer.

The report also summarises the status of the implementation of Articles 9 and 10 of the Energy Efficiency Directive on metering and billing as reported by Member States themselves in their 2014 National Energy Efficiency Action Plans that Members States submitted in accordance with the EED, focusing on the latest developments of the roll-out of Smart Meters, individual energy measurements and billing in terms of the information available to consumers and the periodicity of billing and readings, where the bills need to be based on real consumption, be delivered frequently to final consumers and historical consumption should be made accessible.

The outcomes of a workshop organized by the Joint Research Centre on the "Provision of consumption information to final customers - EC support to the Implementation of EED Article 10 in relation to billing information" were also taken into consideration for this report (see Annex I for a summary of the workshop presentations). It has to be noted that in terms of heat metering, the Joint Research Centre has developed a report on "Accurate metering and billing of individual consumption of heating/cooling and domestic hot water in multi-apartment and multi-purpose buildings".

Smart meters have features or functionalities that can change the paradigm in the way energy is being managed. The optimization of grid use and consequent efficiency of the grid, especially the distribution network, where network losses are sometimes significant; the possibility of accurate and frequent reading, the possibility of getting feedback in real time and the functionality for final energy consumers to access to time of use tariffs. The smart meter roll out should allow for a much greater interaction between final energy consumers and energy system operators allowing the consumers to base their choices, in terms of actual energy consumption, while stimulating energy savings, providing at the same time a natural increase of efficiency, especially in the Distribution System Operators thanks to the easy access of consumption patterns, allowing networks to act on actual updated data in order to manage networks assets in a much more concerted way.

The fact that smart meters can be connected to other devices in the "connected home" should ultimately allow for a much more effective energy management for final consumers. While there may still be a long road for the full deployment of smart meters all over the EU, the fact that consumers may be able to access the accurate registry of their own energy consumption through individual measurements, receive further information on the types of tariffs and get advice on how to save energy in their bills, presents a valid potential in order to reduce energy consumption in final consumers.

1.1. Energy Feedback

Energy Feedback is a way to turn a resource that until recently was more or less invisible to energy consumers into a visible one, having ultimately the possibility of turning energy consumers from a passive state into an active one.

This change of paradigm makes it possible to trigger energy savings thanks to the actions stimulated from the collected and processed energy consumption information and the consequent action from the consumer when the consumer is properly engaged.

Ultimately there are two types of Feedback: Indirect and Direct. There have been described sub-categories under these two types of feedback, allowing different types of interaction and response from the energy providers and energy users.

Table 1 – Types of Feedback

Type of Feedback	Sub-type of Feedback	Medium	Type of information	Communication
Indirect Feedback	Standard Billing	Paper	- Historical Energy consumption - Historical comparison	One way communication
	Enhanced Billing	- Paper - Electronic environment (e-bill)	- Energy consumption, rewards - Energy Efficiency Advice - Social comparison - Historical comparison	One way communication
Direct Feedback	Direct feedback with IHD	- In-House Display - Web environment	- Real-time information - Social comparison - Historical comparison	One way communication
	Direct with Connected Devices	- In-House Display - Web environment - Smart Meter	- Real-time information - Appliance disaggregation - Social comparison - Historical comparison	Two-way communication

Indirect Feedback Systems are the most common systems accessible for energy consumers, consisting in energy feedback provided after the consumption. Indirect Feedback may be divided into two different sub-categories:

a) **Standard billing**: common energy bills belong to the first sub-category of Indirect Feedback and are usually provided by the energy retail supplier. This type of feedback is usually only describing the amount of energy consumed for a determined period of time through a paper bill or in an electronic format providing little information.

b) **Enhanced billing**: the second sub-category of Indirect Feedback also relates to already measured energy consumption, but this type of feedback provides whole house feedback, while giving an historical and social comparison and context. It may be provided by a third party company that analyses the information collected by the utility company.

Standard billing a) as mentioned before, is the typical energy bill, that arrives with a certain periodicity to the final consumer. Standard billing is the least effective type of feedback in terms of making consumers reduce energy consumption or energy waste, but it is also a low or no cost option since consumption has to be billed in any case for commercial reasons. The type of information in a typical energy bill does not go much further than the presentation of the cost, type of tariff and a comparison with a similar period of time. This type of feedback, besides informing the final consumer to pay the bill, does not present a strong call for action in any way. It is only an informational and non engaging. In some countries, the lack of clarity in the bill is noticeable, leading to confusion and lack of interest. Annex VII of the Energy Efficiency Directive gives guidance on the type of information to be provided to final costumer.

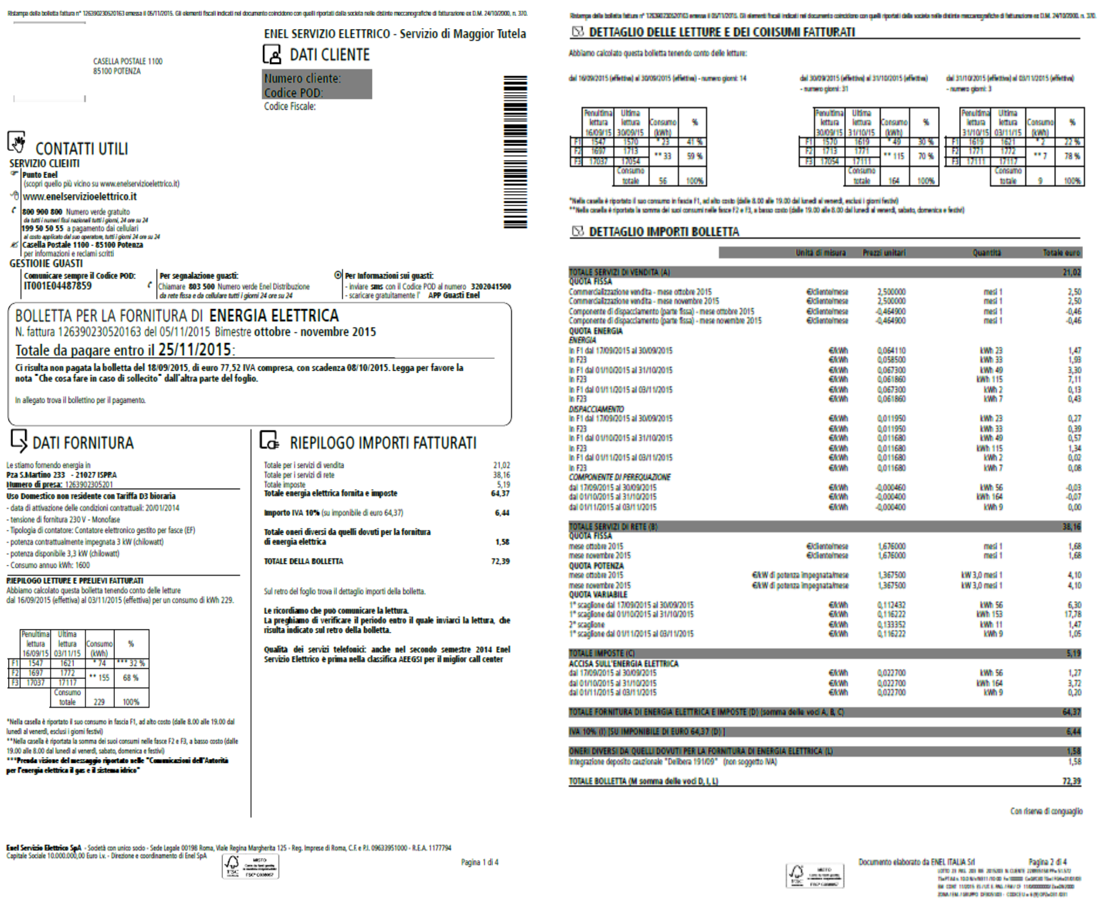


Figure 1 – Example of an Italian Standard Energy Bill

The second type of indirect feedback category (b)) is an enhanced type of feedback, that can be associated with the energy bill or not, and is provided through mailings and/or through a web environment that can be accessible through computer or mobile apps. The type of information in these advanced indirect feedback systems is more elaborated than the more common, basic bills, and generated on the basis of a variety of data sources besides the typical utility data, like assessor parcel maps, home audits or census. The use of statistical data is commonly used by third-party companies that develop algorithms to analyse existing data and user input to provide a more personalized experience for the user. The amount and quality of information is then much richer with household information and advice, web-based energy audits and billing analysis being given. Also behavioural principles are being used in order to promote the engagement of the energy consumers. Tools using gamification principles like social comparisons, goal setting, personal comparison and call-to-action measures are commonly used in these types of feedback systems.

This type of Enhanced billing has been developed in the last years with success by companies such as OPOWER, working with utilities and applying recent findings in social science. Behavioural science, Big data analytics and user-centric design are seen as the tools for developing their energy conservation programs that are then used by the utilities to communicate more effectively with their customers.

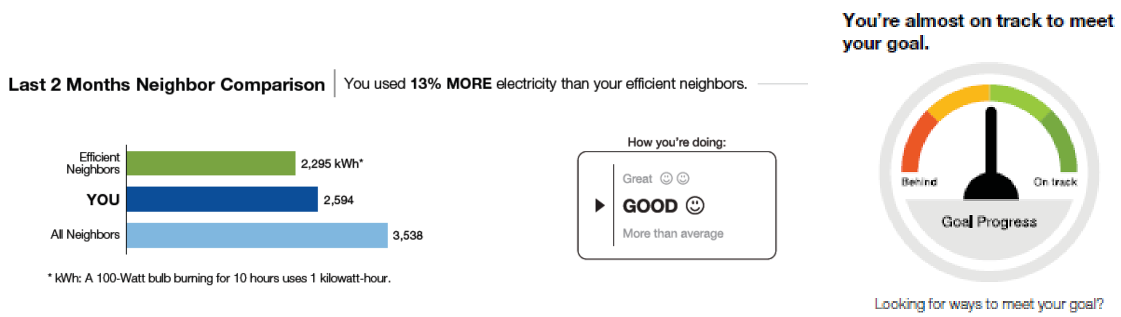


Figure 2 – Behavioral science insights in OPOWER Home Energy Reports

As can be seen in the figure above, the way of presenting the customers performance in an easy way to read and understand, descriptive and injunctive norms are used to motivate and reinforce positive behaviour change as the costumer can see where he/she stands in comparison with their neighbours and receive an immediate gratification for example in the form of an emoticon (e.g. ☺). The same applies for goal setting where the costumer is encouraged to commit to a specific goal and subsequently more likely to act accordingly.

Besides the common use of a billing event as a moment to communicate with the costumer, companies choose also other key moments throughout the year. There are different moments chosen for engagement where an utility costumer receives some kind of communication. The type of communication is not always the same as is the case with standard bills, but tailored to a specific occurrence. Some of these moments are already depending on a smart meter installation, while some can occur in the presence of traditional meter technologies. For example, when there is a seasonal change, a communication piece is sent to the consumer in order to adapt their household for the specificities of the arriving season, often with advice on technologies to implement or simple behavioural changes to be incorporated in the daily life. Other type of moments can be when a high bill is expected to come, on a peak day, on a possible rate change or in the case of extreme weather or outage.

The introduction of new means to control in an automatic and remote way the spaces used by final energy consumers, going towards a concept of a connected home, where control systems communicate with appliances and energy providers, can ultimately present an opportunity to improve energy efficiency both in the Demand as in the Energy Supply side. It is here that **Direct Feedback** comes into play.

Direct feedback can also be divided into sub-categories:

(i) **Direct Feedback using In-Home Displays (IHD)** where a device is installed in the home environment allowing the energy user an access of real-time information on the energy use, allowing energy users to learn about the consumptions of different appliances by turning on and off the home devices, receiving immediate appliance-specific feedback. The In-House energy Displays are installed by clamping the device into the main electricity panel (for electric energy) allowing at least information at a household level, while some can even give a disaggregation at a space level (kitchen, living room, bedroom). Lately, with the roll-out of smart meters, clamping the IHD into the electricity panel has been substituted by a direct connection to the smart meter, usually via a wireless system.

These devices can give information on the energy use in terms of cost and can be also associated to a web environment providing extra information allowing for alarm setting and goal tracking, if the user wishes. This type of feedback systems cannot, however, be operated in terms of demand response and dynamic pricing signals, since are one-way communication devices.

(ii) **Direct feedback with "Connected Devices" and Automation** is the most complete and engaging type of feedback before a fully automated system. To reach an accurate and effective feedback system, the user needs to have their home connected to a central device or web application, being able to control remotely at an appliance level the functionalities of the home, while having the ability even to receiving pricing signals and utility load control. These types of systems include several features and components, usually required to be installed by the user, ranging from in-home energy displays, smart thermostats, smart plugs and smart lighting and appliances. This type of can provide an appliance and end-use disaggregated feedback. This type of feedback gives estimated appliance specific feedback, historical and social comparisons. The method being used for this disaggregation named NILM (Non-Intrusive Load Monitoring) and requires some supervision from the energy consumer, at a first stage at least, to set up a correspondence between the load signals and the algorithm to interpret such signals.

Although, like mentioned before, some companies are dedicating their action towards Indirect Feedback, these too can beneficiate from a connection to the smart meter, thus providing more accurate and reliable information. There are, however, companies that are focusing on promoting energy efficiency through direct feedback, using similar tools as the ones described previously in order to give valuable insight to final consumers.

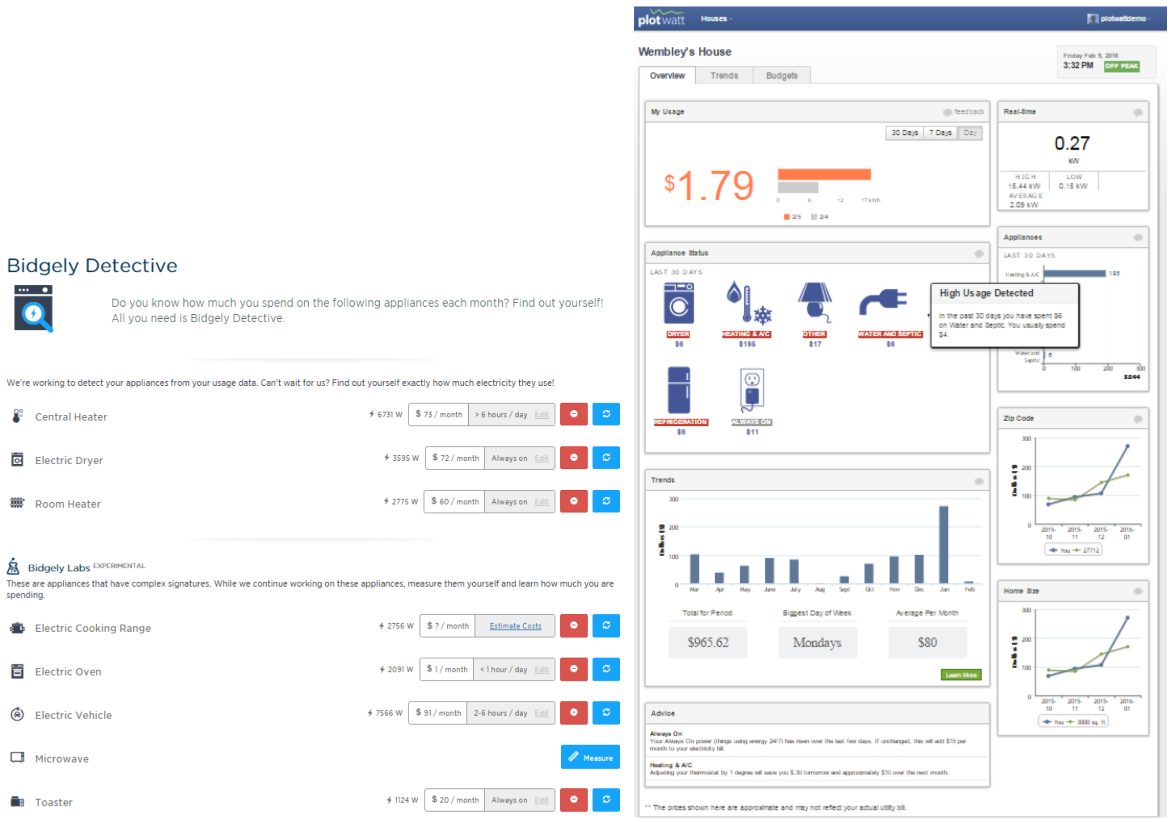


Figure 3 – Example of direct feedback interface with disaggregation by appliance

Companies like Plottwatt or Bidgely (Figure 5) provide direct feedback to costumers directly or through utilities in a B2B model, being able to give information up to the level of domestic appliances. This type of feedback reaches its full potential when connected with a smart meter, while being part of a smart grid, giving the ultimate possibility of Demand Response, thus potentiating the efficiency of the networks' efficiency.

Overall the main differences between Indirect and Direct Feedback can be divided into three issues:

- Frequency: Indirect Feedback has a lower frequency (monthly bills at best in the case of standard billing)
- Medium: Direct feedback uses IoT devices for communication between the user and the utility, while indirect feedback is yet mainly through paper mailing.
- Communication: Indirect Feedback is one-way communication, while Direct Feedback can be two-way communication between the user and utility.

1.2. Feedback in the context of the Energy Efficiency Directive

There are provisions in the Energy Efficiency Directive specifically aimed at ensuring energy consumption feedback. The first is metering (Article 9) and the requirement to provide to final costumers individual meters for electricity, natural gas, district heating, district cooling and domestic hot water reflecting the actual energy consumption, providing information on actual time of use. This complements provisions on roll-out of smart meters in the Electricy and Gas Market Directives.

The second step for energy feedback in the EED is the use of information from such meters for billing and billing information (Article 10).

In terms of periodicity of the billing, according to EED Annex VII, bills on the basis of actual consumption must as the general rule be provided at least once a year. Where smart meters are not available, where technically possible and economically justified: by 31 December 2014, billing information based on actual consumption is to be made available at least quarterly, on request or where the consumers have opted to receive electronic billing or else twice yearly.

In the case where meters are not available, the obligation on billing information can be fulfilled by a system of self-reading. In such cases, billing and billing information can be based on estimated consumption or a flat rate only if the final customer did not provide the reading.

The critical point for the mandatory character of accurate billing information based on actual consumption is the availability of individual metering equipment as stated in Article 9 of the EED.

Smart meters are expected to lead to a reduction in energy consumption by changing consumer behaviour through information on energy consumption, and better energy accounting overall. The European Commission has stated the view that where smart metering is available to final customers, billing information based on actual consumption should be provided on a monthly basis[1].

[1] Cf. para 37 of SWD(2013) 448 final, http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52013SC0448

2. Member State NEEAP Analysis

In the articles 9 to 11 of the Energy Efficiency Directive relating to Metering and Billing, the EED aim that final consumers obtain accurate and up to date information relating to their energy consumption for all types of energy sources. In the case of Member States without the smart meter infrastructure already deployed, there is an obligation for these Member States to ensure that, by the 31st of December 2014, billing information is accurate, based on actual consumption and provided with a minimum frequency as set in Annex VII of the EED. Also, in the case of Member States already implementing smart metering systems, the EED also clarifies some obligations for establishing minimum functionalities and obligations for market participants in terms of billing information based on actual consumption.

There are five main issues relating to the afore mentioned EED articles that concern the objective of this study and can positively influence the increase of energy savings through an improvement of the information provided to costumers in energy bills and the potentialities arising from the deployment of smart meters infrastructures. These five issues are the roll-out of smart meters, the measurements of individual energy consumptions, the information provided on energy bills, the periodicity of the bills and the periodicity of the readings.

In terms of the roll-out of Smart Meters, Brussels capital and Wallonia and CZ are not considering the installation of a smart meter infrastructure because of not being cost-effective, while AT, BE Flanders, CY, DK, EE, FI, FR, IT, LV, LT, LU, MT, NL, PT, SK, SL, ES, SE, UK are already deploying their smart meter infrastructure.
To be noted that FI and IT have already the great majority of energy consumers connected to a remote read meter.
Pilots for the installation of smart meters have been concluded on EL and RO and ongoing in HU and PL. IE has concluded its pilot studies and is starting a wide smart meter installation in 2016.

No information regarding the roll-out of Smart Meters has been described in the NEEAPs of BG and DE, while HR was in an evaluation process at the time of the NEEAP writing.
In the great majority of the Member States the responsible party to implement the roll-out of Smart Meters are the DSO operating in such markets.

Regarding the Individual consumer measurements, the majority of the Member States have declared to have in place individual measurements for the final energy consumers, mainly in electric energy.

Also for the extended information to be present in energy bills, the majority of Member States have in place measures to provide energy consumers with information regarding historic information, explanation of tariffs and price details, with many of the Member States using electronic based information systems to provide further information for their customers. Electronic reporting feedback has been mentioned in the BE Wallonia, DK, EE, FI, EL, LU, SE, UK,

No measures regarding Articles 9-11 of the EED were presented by Germany. It was only stated that no conclusions on the smart meter service market can be made due to analytical difficulties.

The periodicity of readings and billing are the issues not thoroughly outlined in the NEEAPs. The Member States with already a Smart Meter infrastructure well developed are able to provide regular monthly or bi-monthly billing thanks to the almost immediate readings allowed by the functionalities of the meters. Other Member States with the Smart Meter process underway have implemented measures to provide at least one reading per year, with a periodicity of billing varying from yearly to four times a year.

Table 2 summarizes the status of the five issues reported in the Member States NEEAPs.

Table 2: Status of main issues related to feedback reported in the MSs' NEEAPS.

Member State	Roll out of Smart Meters	Individual Consumer Measurements	Bill Information	Periodicity of Billing	Readings
Austria	From 2012; large scale deplyoment: 10% by 2015, 70 % by 2017, 95% by 2019 for all electricity consumers	Implemented	Complete information	Smart Meter: 1x/ month Normal Meter: 1x/ year	Smart Meter: 4x/hour for electricity 1x/day for gas, plus reading 1x/day Normal Meter: 1x/year
Belgium Brussels Capital	Not until 2018	Implemented	Complete information	Not clear	At least once a year
Belgium Flanders	Pilots ongoing (41000 meters). No final decision on the roll out of smart meters	Implemented	Historical information and further detailed information upon request	Not clear	At least once a year
Belgium Wallonia	Not cost effective	Implemented for new and refurbished buildings	E-bills with historic information, energy consumption, advice	Not clear	At least once a year
Bulgaria	No information	Implemented	Additional information on energy bills to be implemented in 2014. Type of information complete	No periodicity indicated.	No information
Croatia	At an evaluation stage at the time of NEEAP	Implemented	From 2014 to 2016 will introduce clear and comprehensive energy bills	No periodicity indicated	No information
Cyprus	300k smart meters with structural funds aid	Implemented	No information	No information	No information
Czech Republic	No wide-scale roll-out foreseen	Implemented for Electricity. Heat and Hot water meters to be installed individually in radiators.	Bills provide economic information itemizing individual parts of the payment	Monthly	Quarterly or Annual Settlements

Member State	Roll out of Smart Meters	Individual Consumer Measurements	Bill Information	Periodicity of Billing	Readings
Denmark	Ongoing from 2011. Up to 2020 all meters will be remotely read	Implemented for new and refurbished buildings. By 2016 all consumptions are to be individualized.	All consumers receive information on energy consumption, comparison with previous year and similar consumers. Information accessible through web app for electricity consumers.	Quarterly	Yearly
Estonia	Starting from 2014. All meters to be smart by 2020	Implemented	Information can be accessed through web environment	Not clear	Smart meter: At least daily
Finland	Big majority of electricity and heat consumers already with remotely read meters. 100 % by 2020 expected	Implemented for electricity and new and refurbished projects	Electronic reports and normal bills with information and advice on savings	Not clear	Hourly for Smart meters
France	Wide-scale roll-out ongoing. Should be completed by 2020	Implemented	All consumers receive information on energy consumption, comparison with previous	At least once a year	Once a year. Consumers can supply information on their consumption
Germany	No information in NEEAP. Selective roll-out of Smart Meters by 2020.	No information	No information	No information	No information
Greece	Pilot project finished. Expected 80% of smart meters by 2020.	Implemented for electricity	Electronic bills available. Some natural gas consumers can access to extended information on their consumptions.	At least every four months for electricity and gas	At least every four months for electricity and gas
Hungary	Pilot ongoing. No wide-scale roll-out information	Implemented	Consumption and billing data are freely available for consumers	No information	Billing made according to real consumption
Ireland	Pilot finished. Wide smart meter installation to begin in	Not clear	Complete information with consumption comparison and advice	Regular scheduled bills	Quarterly

Member State	Roll out of Smart Meters	Individual Consumer Measurements	Bill Information	Periodicity of Billing	Readings
	2016 for a 100% coverage by 2020.				
Italy	Already in place for electricity. 60% of gas smart meters expected by 2018.	Implemented for free market	Current Electricity and Gas bill already comply with EED requirements. Authority website provides further information on the bills and a comparison between different energy suppliers.	Bi-monthly	4x/hour
Latvia	Selective roll-out ongoing	Implemented for new and refurbished buildings	Smart meter project provides complete bill information on energy consumptions.	Not clear	Not clear
Lithuania	No indication of smart meter strategy. 57% of Electricity already with remote reading	Not clear	Information on actual consumption	Quarterly	At least yearly
Luxembourg	From 2015 for all new costumers and costumers having meters replaced. 95% expected by 2020	Not clear	Information on current prices, energy consumption, comparison with same period. Possibility to receive e-bill.	At least 2x/year or quarterly if requested	At least yearly until all consumers have smart meters
Malta	Implement ed	Implemented	Complete information	Bi-monthly	2x/year before entering of Smart Meters
Netherlands	Ongoing	Implemented	Ok for electricity, amendments needed for heating and cooling	Bi-monthly for smart meters	Not clear for non-smart meters
Poland	Starting from 2012 with pilots.	Not clear	Not clear	Not clear	Not clear
Portugal	Roll-out ongoing. 100% expected by 2020.	Implemented	Information present in bills	Not clear	Not clear
Romania	Pilots implement ed. 80 % by 2020, starting in 2015	Implemented	NEEAP mentions Articles 9-11 are already transposed. Not clear at what extent	Not clear	At least yearly

Member State	Roll out of Smart Meters	Individual Consumer Measurements	Bill Information	Periodicity of Billing	Readings
Slovakia	Ongoing. Mandatory for households with consumption over 4MWh (22% of households)	No information	No information	No information	No information
Slovenia	Ongoing (29% in 2013)	Not clear	e-portal with complete information on energy offers	Not clear	At least yearly. Possible for costumer to communicate monthly readings
Spain	Ongoing. To be finished by 2018	From 2017 onwards	No information	No information	No information
Sweden	Roll-out ongoing. 100% by 2020		Information on bills, completed by online information	Quarterly	Not clear
UK	Ongoing	Implemented	Clear bills with information on consumptions. Most e-bills.	Quarterly	At least yearly

3. Analysis of Meta-data studies on Feedback

In order to quantify the effect of feedback on energy consumption, a large number of studies have been carried out in the past 40 years. In this report we refer to the experiences already summarised in recent literature review papers, and in particular to those of E. Zvingilaite and M. Togeby (Zvingilaite, 2015), and B. Karlin, J. F. Zinger, and R. Ford (Karlin, 2015). These reviews analysed past empirical studies on consumption feedback through qualitative methods of literature review, in which a set of empirical experiences on a specific topic are collected, classified, and summarised. Doing this task, these authors applied some inclusion criteria to ensure that the studies included in their analysis pass at least a minimum standard of quality (e.g. by excluding studies that did not have a control group as well as those with clear confounding variables).

In this way we collected a final dataset of 118 feedback applications, which cover:

- 3 consumption types (electricity only, electricity and heating, heating only);
- 16 different Countries (mainly in North America and North Europe);
- 2 feedback types (direct and indirect);
- 6 media types (bill, card, In-House-Display (IHD), mail, PC or web, mixed mode);
- A large range of sample sizes (from about 10 to almost 100 000 households);
- Different duration periods (from 2 weeks to 3 years).

Table 3 shows the percentage energy savings achieved by all these studies, in comparison with the main factors characterising the experiences.

Table 3: Summary of relevant feedback studies.

Study	Consumption Type	Country	Feedback type	Media	Frequency	Sample size	Duration [months]	% Savings
Allcott (2010)	Electricity	USA	Indirect	Bill	Monthly	78492	9	2.4%
Allcott (2009) a	Electricity	USA	Indirect	Mixed	Monthly	23530	12	2.0%
Allcott (2009) b	Electricity	USA	Indirect	Mixed	2-6 months	15687	12	1.5%
Allen & Janda (2006)	Electricity	USA	Direct	IHD	Continuous	60	2	-
Arvola et al. (1994)a	Electricity and Heating	FI	Indirect	Bill	Monthly	180	30	3.0%
Arvola et al. (1994)b	Electricity and Heating	FI	Indirect	Bill	Monthly	173	30	5.0%
Ayres et al. (2013)	Electricity and Heating	USA	Indirect	Bill	Monthly	84000	9	1.2%
Battalio et al. (1979); Winett et al. (1978)	Electricity	USA	Indirect	Card	1-4 times/week	70	0.5	0.9%
Becker & Seligman (1978); Seligman et al. (1978) Study 3	Electricity	USA	Indirect	Card	1-4 times/week	20	0.5	15.7%
Becker (1978); Seligman et al. (1978) Study 2	Electricity	USA	Indirect	Card	1-4 times/week	80	0.5	13.0%
Benders et al. (2006)	Electricity	NL	Indirect	PC or Web	-	137	5	9.0%
Bittle et al. (1979)	Electricity	USA	Indirect	Card	Daily	30	2	-
Bittle et al. (1979–1980)	Electricity	USA	Indirect	Card	Daily	353	0.5	-
Brandon and Lewis (1999)	Electricity and Heating	UK	Indirect	PC or Web	Monthly	28	9	4.3%
Carroll et al. (2013), A	Electricity	IE	Indirect	Mail	2-6 months	656	12	0.4%
Carroll et al. (2013), B	Electricity and Heating	IE	Indirect	Bill	Monthly	672	12	3.0%
Carroll et al. (2013), C	Electricity and Heating	IE	Direct	IHD	Continuous	636	12	2.0%
DECC (2015)	Electricity	UK	Direct	IHD	Continuous	5145	12	2.3%

Study	Consumption Type	Country	Feedback type	Media	Frequency	Sample size	Duration [months]	% Savings
DECC (2015)	Heating	UK	Direct	IHD	Continuous	5145	12	1.5%
DENA (2014)	Heating	DE	Indirect	Mail	Monthly	145	12	9.0%
Dobson and Griffin (1992) in Darby (2006)	Electricity and Heating	CA	Direct	IHD	Continuous	< 100	2	13.0%
D'Oca et al. (2014)	Electricity	IT	Direct	IHD	Continuous	31	12	18.0%
E.ON/AECOM 2011 a' (fuel poor)	Electricity	UK	Indirect	Bill	Monthly	2639	24	-2.0%
E.ON/AECOM 2011 a' (fuel poor)	Heating	UK	Indirect	Bill	Monthly	2639	24	4.4%
E.ON/AECOM 2011 a'' (high use)	Electricity	UK	Indirect	Bill	Monthly	2639	24	2.0%
E.ON/AECOM 2011 a'' (high use)	Heating	UK	Indirect	Bill	Monthly	2639	24	2.3%
E.ON/AECOM 2011 a''' (not fuel poor)	Heating	UK	Indirect	Bill	Monthly	2639	24	3.6%
E.ON/AECOM 2011 b'	Heating	UK	Indirect	Bill	Monthly	2639	24	6.7%
E.ON/AECOM 2011 b''	Heating	UK	Indirect	Bill	Monthly	2639	24	2.5%
E.ON/AECOM 2011 b' (fuel poor)	Electricity	UK	Indirect	Bill	Monthly	1436	24	-2.0%
E.ON/AECOM 2011 b'' (high use)	Electricity	UK	Indirect	Bill	Monthly	1436	24	3.0%
E.ON/AECOM 2011 c'	Heating	UK	Indirect	Bill	Monthly	1436	24	7.2%
E.ON/AECOM 2011 c''	Heating	UK	Indirect	Bill	Monthly	1436	24	2.4%
E.ON/AECOM 2011 c' (fuel poor)	Electricity	UK	Indirect	Bill	Monthly	1456	24	-1.0%
E.ON/AECOM 2011 c'' (high use)	Electricity	UK	Indirect	Bill	Monthly	1456	24	2.0%
E.ON/AECOM 2011 d'	Heating	UK	Direct	Mixed	Mixed	1436	24	4.6%
E.ON/AECOM 2011 d''	Heating	UK	Direct	Mixed	Mixed	1436	24	2.2%
E.ON/AECOM 2011 d' (fuel poor)	Electricity	UK	Direct	Mixed	Mixed	2524	24	2.0%
E.ON/AECOM 2011 d'' (high use)	Electricity	UK	Direct	Mixed	Mixed	2524	24	4.0%
E.ON/AECOM 2011 d''' (not fuel poor)	Heating	UK	Direct	Mixed	Mixed	1436	24	4.9%

Study	Consumption Type	Country	Feedback type	Media	Frequency	Sample size	Duration [months]	% Savings
E.ON/AECOM 2011 e	Electricity and Heating	UK	Direct	Mixed	Mixed	2524	24	3.0%
EDF/AECOM 2011 a	Electricity	UK	Indirect	Mail	Monthly	386	20	2.0%
EDF/AECOM 2011 b	Electricity	UK	Direct	IHD	Continuous	370	20	5.0%
EDF/AECOM 2011 c	Electricity	UK	Direct	IHD	Continuous	200	20	7.0%
Garay and Lind-holm (1995)	Heating	SE	Indirect	Mail	Monthly	600	15	n.a.
Garay and Lindholm (1995) in Darby (2006)	Electricity and Heating	SE	Indirect	Mail	Monthly	600	15	n.a.
Gleerup et al. (2010)	Electricity	DK	Indirect	Mixed	Mixed	194	12	2.5%
Haakana (1997)	Electricity	FI	Indirect	Mail	Monthly	79	20	13.5%
Haakana (1997)	Heating	FI	Indirect	Mail	Monthly	< 100	20	6.0%
Harrigan and Gregory(1994)	Heating	USA	Direct	IHD	Continuous	71	14	0.0%
Hayes & Cone (1981)	Electricity	USA	Indirect	Card	Monthly	40	5	7.0%
Henryson et al. (2000) in Fischer (2008)	Electricity	DK-SE	Indirect	Mail	Monthly	3500	n.a.	7.0%
HER (2012) b	Electricity	USA	Indirect	Mixed	2-6 months	50000	12	1.0%
HER (2012) b	Heating	USA	Indirect	Mixed	2-6 months	50000	12	0.7%
Houwelingen (1989) a	Heating	NL	Direct	IHD	Daily	50	12	8.0%
Houwelingen (1989) b	Heating	NL	Indirect	Mail	Monthly	50	12	3.0%
Houwelingen (1989) c	Heating	NL	Direct	IHD	Continuous	50	12	1.0%
Hutton et al. (1986) Study 1	Electricity	USA-CA	Direct	IHD	Continuous	371	5	4.1%
Hutton et al. (1986) Study 2	Electricity	USA-CA	Direct	IHD	Continuous	377	5	5.0%
Hutton et al. (1986) Study 3	Electricity	USA-CA	Direct	IHD	Continuous	336	5	6.8%
Hydro One (2006)	Electricity	CA	Direct	IHD	Continuous	500	30	7.0%
Hydro One (2006) b	Electricity and Heating	CA	Direct	IHD	Continuous	500	30	1.2%
Hydro One (2006) c (electric hot water heating)	Electricity and Heating	CA	Direct	IHD	Continuous	500	30	16.7%

Study	Consumption Type	Country	Feedback type	Media	Frequency	Sample size	Duration [months]	% Savings
ISTA (2011)	Heating	DE	Indirect	PC or Web	Monthly	n/a	6	14.0%
Kasulis et al. (1981)	Electricity	USA	Indirect	Bill	Monthly	390	5	-
Katzev et al. (1980–1981)	Electricity	USA	Indirect	Card	Mixed	22	0.5	15.0%
Kofod (2013), CUB	Electricity	USA	Indirect	Mail	-	2457	n.a.	4.4%
Kurz et al. (2005)	Electricity and Heating	AU	Indirect	Card	1-4 times/week	423	5	0.0%
Mack and Hallmann (2004) Fischer (2008)	Electricity	DE	Indirect	Mail	1-4 times/week	19	n.a.	3.0%
Mansouri & Newborough (1999)	Electricity	UK	Direct	IHD	Continuous	31	2	20.0%
Matsukawa (2004)	Electricity	JP	Direct	IHD	Continuous	319	5	1.8%
McClelland & Cook (1979–1980)	Electricity	USA	Direct	IHD	Continuous	101	9	12.0%
Midden et al. (1983)	Electricity	NL	Indirect	Card	1-4 times/week	95	2	13.2%
Mosler and Gutscher (2004) Fischer (2008)	Electricity	CH	Direct	n/a	Daily	48	1	6.0%
Mountain (2007) Study 1	Electricity	CA	Direct	IHD	Continuous	118	15	18.1%
Mountain (2007) Study 2	Electricity	CA	Direct	IHD	Continuous	110	15	2.7%
Mountain Economic Consulting and Associates (2006)	Electricity	CA	Direct	IHD	Continuous	552	15	6.5%
Nexus Energy Software (2006)	Electricity and Heating	USA	Indirect	Mixed	Mixed	249	5	19.0%
Nielsen (1992) a	Electricity	DK	Indirect	Mixed	Monthly	500	36	10.0%
Nielsen (1992) b	Electricity	DK	Indirect	Mail	Monthly	500	36	8.0%
Nielsen (1992) c	Electricity	DK	Indirect	Mixed	Monthly	500	36	7.0%
Nilsson et al. (2014) a	Electricity	SE	Direct	IHD	Continuous	20	1	0.0%
Nilsson et al. (2014) b	Electricity	SE	Direct	IHD	Continuous	13	1	0.0%
Pallak & Cummings (1976); Pallak et al. (1980)	Electricity and Heating	USA	Direct	IHD	1-4 times/week	109	2	16.0%

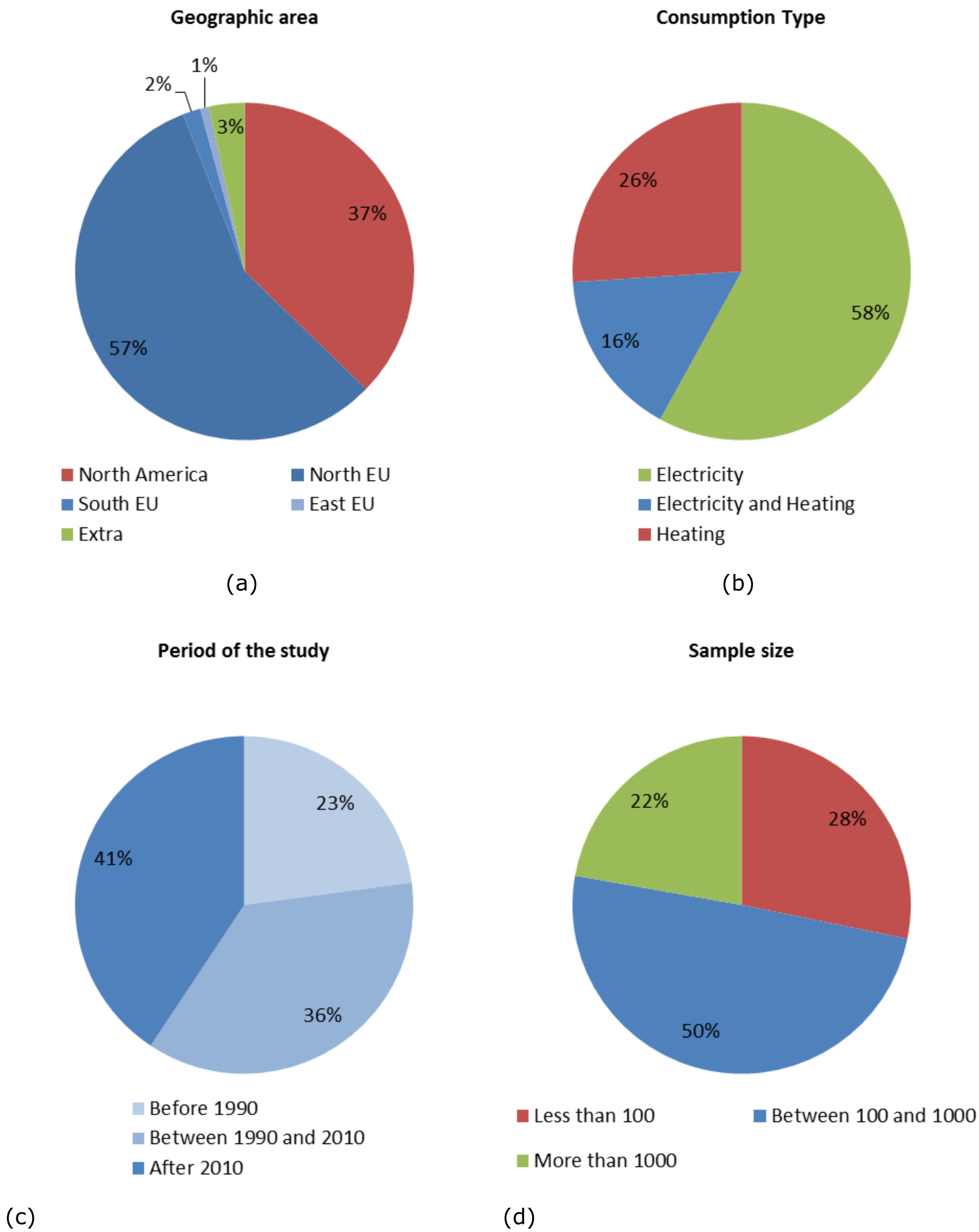
Study	Consumption Type	Country	Feedback type	Media	Frequency	Sample size	Duration [months]	% Savings
Parker et al. (2008)	Electricity	USA	Direct	IHD	Continuous	17	15	7.0%
Robinson (2007)	Electricity	USA	Direct	Mixed	1-4 times/week	141	5	-
Schleich et al. (2011) a	Electricity	DE-AT	Indirect	Mixed	Monthly	1070	12	3.7%
Schleich et al. (2011) b	Electricity	AT	Indirect	Mixed	Monthly	750	12	4.5%
Scottish Power/AECOM 2011	Electricity	UK	Direct	Mixed	Mixed	1603	10	0.0%
Scottish Power/AECOM 2011	Heating	UK	Direct	Mixed	Mixed	1603	9	0.0%
SEAS NVE (2014)	Electricity	DK	n.a.	PC or Web	-	276	12	0.0%
Seaver & Patterson (1976)	Heating	USA	Indirect	Card	Mixed	75	5	-
Seligman et al. (1978) Study 1	Electricity	USA	Indirect	Card	Daily	< 50	1	10.5%
Seligman et al. (1978) Study 2	Electricity	USA	Direct	Card	Continuous	< 50	0.5	13.0%
Seligman et al. (1978) Study 3	Electricity	USA	Direct	IHD	Continuous	< 50	0.5	15.7%
Sexton et al. (1987); Sexton et al. (1989); Sexton & Sexton (1987)	Electricity	USA	Direct	IHD	Continuous	269	9	-
Sipe & Castor (2009) Study 1	Electricity and Heating	USA	Direct	IHD	Continuous	305	9	-
Sipe & Castor (2009) Study 2	Electricity and Heating	USA	Direct	IHD	Continuous	588	9	-
SSE/AECOM 2011 a	Electricity	UK	Direct	IHD	Continuous	2500	36	1.0%
SSE/AECOM 2011 b	Electricity	UK	Indirect	Bill	2-6 months	1902	36	1.0%
SSE/AECOM 2011 c	Electricity	UK	Direct	IHD	Continuous	524	24	2.0%
SSE/AECOM 2011 c	Heating	UK	Direct	IHD	Continuous	204	24	3.0%
Summit Blue Consulting (2009)	Electricity	USA	Indirect	Bill	Monthly	85000	9	2.3%
TREFOR a in Kofod (2013)	Electricity	DK	Indirect	PC or Web	-	90000	12	3.5%
TREFOR b in Kofod (2013)	Electricity and Heating	DK	Indirect	PC or Web	-	10000	12	4.7%
Ueno et al. (2005); Ueno et al. (2006)	Electricity and Heating	JP	Direct	PC or Web	Continuous	19	9	12.0%

Study	Consumption Type	Country	Feedback type	Media	Frequency	Sample size	Duration [months]	% Savings
van Elburg, H. (2008) b	Electricity	IT	Direct	IHD	Continuous	1000	12	10.0%
van Elburg, H. (2008) c	Electricity	NL	Indirect	PC or Web	-	60000	24	3.0%
van Elburg, H. a	Heating	LV	Indirect	Bill	Monthly	22	12	0.0%
van Elburg, H. c	Heating	NL	Indirect	PC or Web	-	60000	24	3.0%
van Houwelingen & Van Raaij (1989)	Heating	NL	Direct	Mixed	Mixed	235	9	12.3%
Wilhite & Ling (1995)	Electricity	NO	Indirect	Bill	Monthly	1284	15	10.0%
Wilhite et al. (1993)	Electricity and Heating	NO	Indirect	Bill	2-6 months	600	36	10.0%
Wilhite et al. (1999)	Electricity and Heating	NO	Indirect	Mail	2-6 months	2000	24	4.0%
Winett et al. (1979) a	Electricity and Heating	USA	Indirect	Mail	Daily	12	1	13.0%
Winett et al. (1979) b	Electricity and Heating	USA	Indirect	Mail	Daily	16	1	7.0%
Winett et al. (1982) Study 1	Electricity	USA	Indirect	Card	Daily	49	2	-
Winett et al. (1982) Study 2	Electricity	USA	Indirect	Card	1-4 times/week	35	0.5	-

3.1 Feedback Studies Breakdown

In order to contextualise better the results shown in section 4 ("Achieved Saving through Feedback"), we presents below the results of a breakdown analysis for the 118 studies listed above. Summarising, the following information can be deduced:

- The majority (57%) of researches have been carried out in North Europe (mostly in UK and Scandinavia) and more than one third (37%) in North America (USA and Canada); other world areas are poorly represented or not at all covered (Figure 4a).
- Large part of studies (58%) focused on the electricity consumptions, but also the effectiveness of feedback on heating consumptions has been well documented (Figure 4b).
- Probably due to increased political focus on energy efficiency and rollout of smart energy metes and online services by energy utilities, the number of studies has increased during the last decade: the 41% of considered researches have been carried out after 2010 (Figure 4c).
- Half of studies were done on samples between 100 and 1000 households and 28% on less than 100 families (Figure 4d).
- The 82% of experiences have had duration greater than 3 months (Figure 4e).
- The majority (59%) of studies focused on indirect means, including feedbacks which have been processed in some way before the user receives it (Figure 4f).
- The recognised studies are representative of a large range of feedback frequencies, but the most represented categories are those of 1-4 times/week and continuous feedback (generally did with an In-House-Display), respectively at 35% and 32% (Figure 4g).
- Large part of direct feedbacks was done using an In-House-Display (IHD), while several different media (but mostly by bill and mail) were used to provide indirect feedbacks (Figure 4h).


Geographic area
1%
2%
3%
37%
57%
North America
North EU
South EU
East EU
Extra
(a)
Consumption Type
26%
16%
58%
Electricity
Electricity and Heating
Heating
(b)
Period of the study
23%
41%
36%
Before 1990
Between 1990 and 2010
After 2010
(c)
Sample size
22%
28%
50%
Less than 100
Between 100 and 1000
More than 1000
(d)

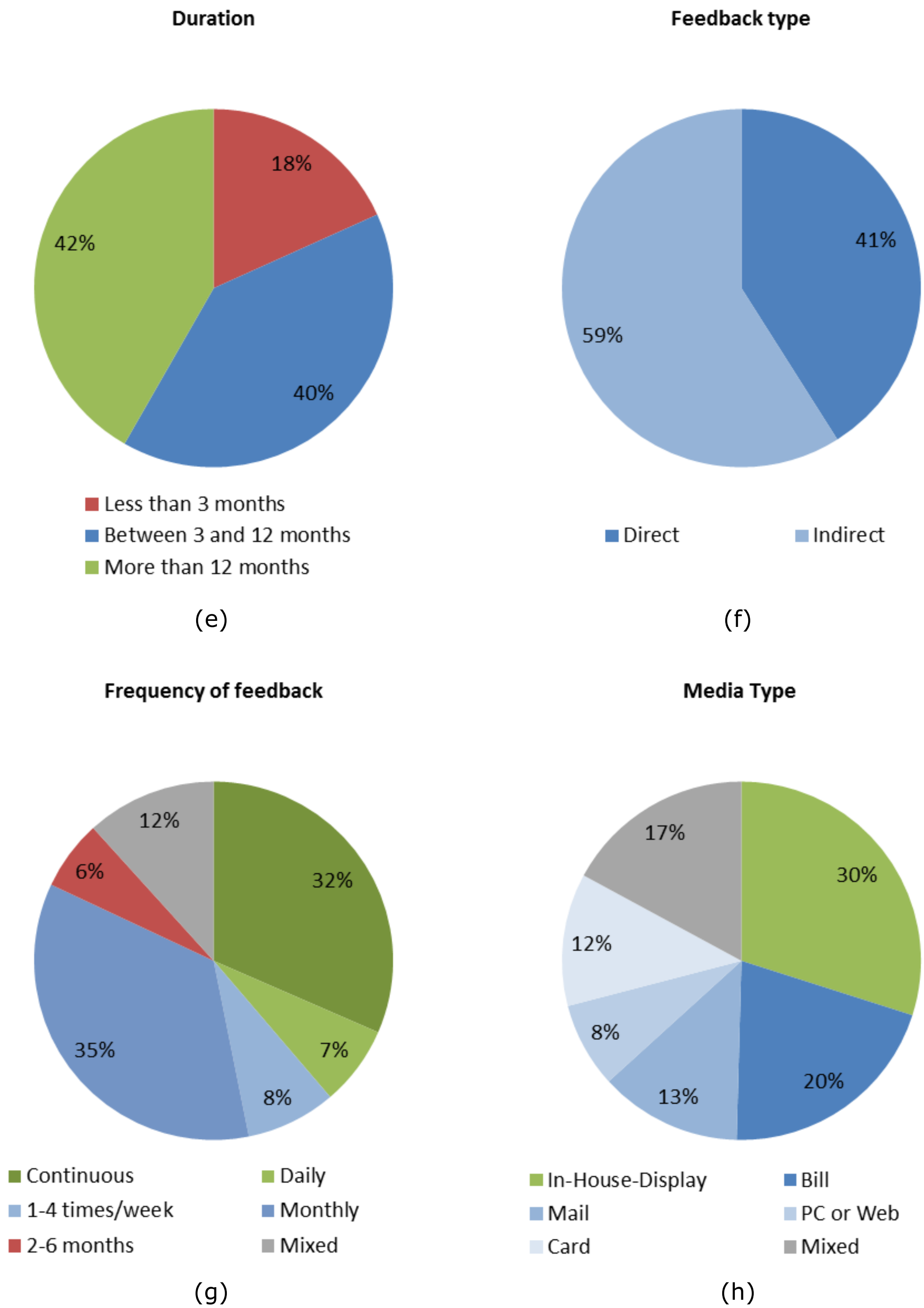


Figure 4: Breakdown of studies taken into account.

4. Achieved Savings through Feedback

Both theory and past empirical research suggest that feedback may have a key role in engaging users in residential energy conservation by making consumers aware of the energy impacts of the household behaviours. However, analysing and comparing the past literature, it is important to remark again that the considered studies have been differently designed, focusing on different energy consumption types and applying different methodologies. As such, the effect of a feedback strategy relevantly varies based on both how and to whom it is provided.

For this reasons it is not trivial to derive absolute evidences by analysing and comparing the energy savings observed. However some general indications can be obtained, by classifying and categorising the results by the main contextual and methodological characteristics. In the following chapters the results of this kind of analysis are presented and discussed.

4.1 Savings per consumption type and geographical area of the studies

Firstly it is interesting to observe that the main energy savings (around 20%) were recorded on the electrical consumptions, independently of the location (if we consider as statistically insignificant the two studies labelled as "Extra").

Where the feedback was applied also on the heating consumptions, the differences between North EU and North America are more pronounced: while in USA a maximum of 19% was obtained, in North Europe (i.e. in Norway) it was only 10%.

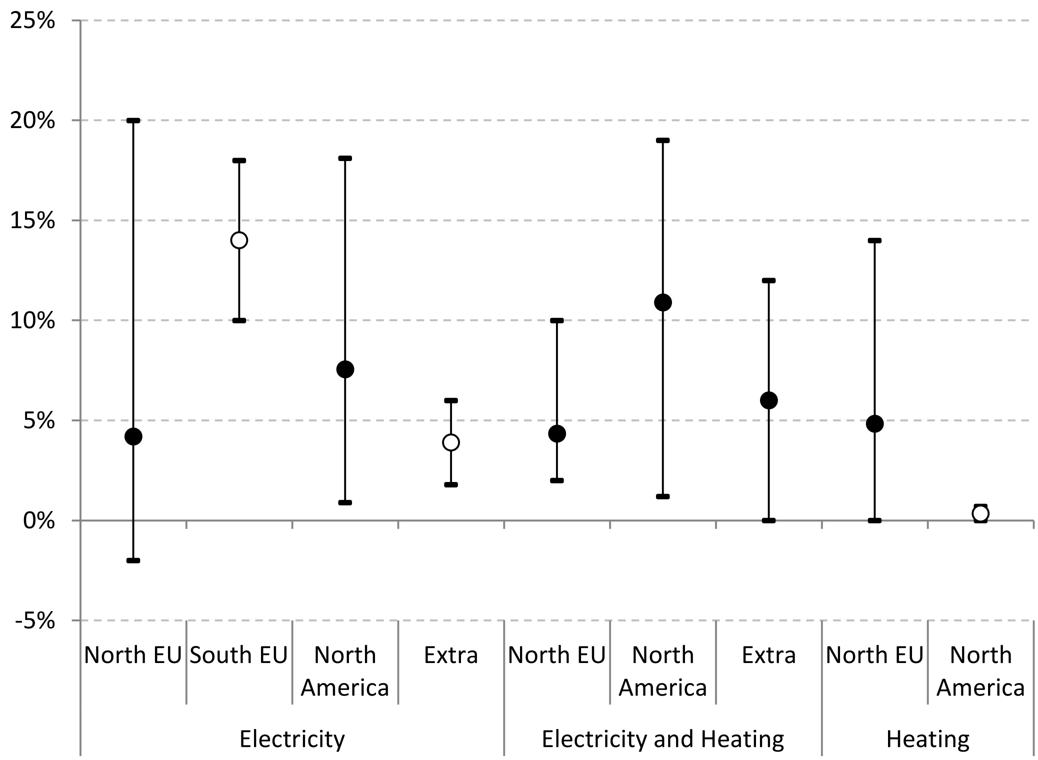


Figure 5: Maximum, minimum and average savings per consumption type and geographical area. White average bullets refer to dataset composed by few studies (i.e. ≤3).

4.2 Savings per consumption and feedback type

By grouping the achieved results per consumption and feedback type (Figure below), we can observe how generally a higher (average) saving is associated to the direct feedback respect the indirect one. This is true when the feedback is applied on the electricity consumption (7% versus 5%) and on the electricity and heating ones (9% versus 7%), but when we analyse the feedback on (only) heating this rule fails. In this case both maximum (14% versus 12%) and average (5% versus 4%) savings are higher for indirect feedbacks.

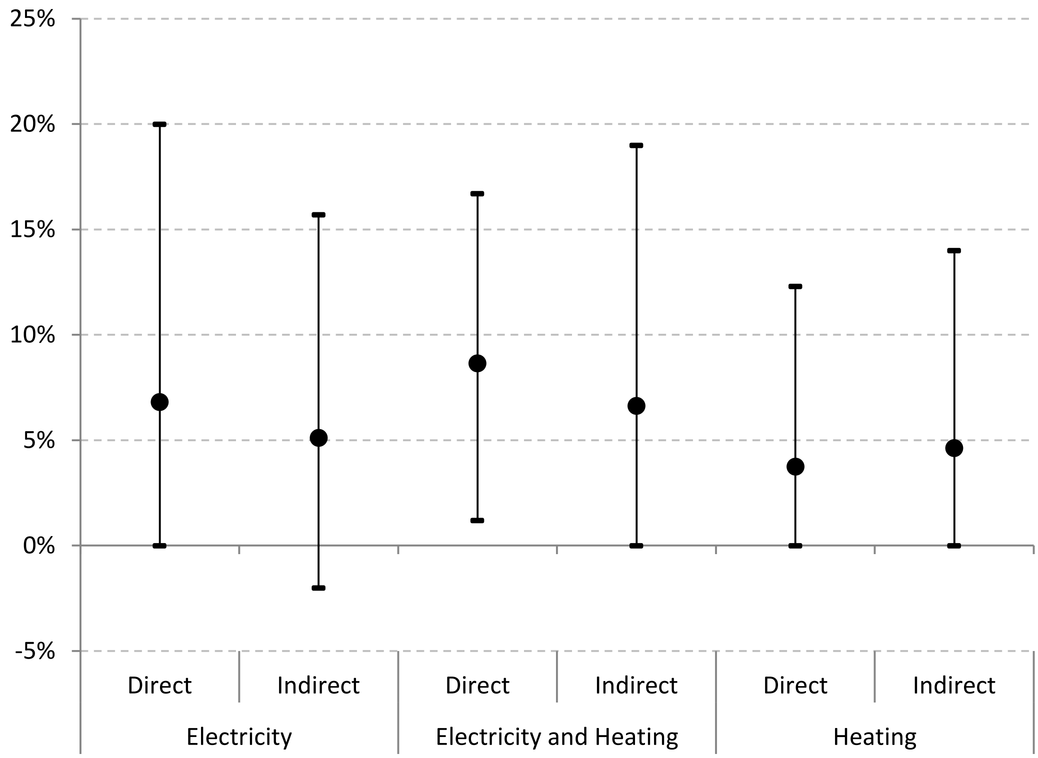


Figure 6: Maximum, minimum and average savings per consumption and feedback type.

4.3 Savings per consumption type and the period of the study

Looking at Figure 7 it is quite evident how the average savings depend on the year of the studies. As the common sense would suggest, the feedback effectiveness is related (inversely) to the grade of awareness of building occupants: in other words, the feedback is more effective in presence of a less conscious behaviour of the users. Assuming that awareness is increasing over time, this could explain that for all consumption types the average savings before 1990 are greater than those recorded after 2010. Also the fact that appliances and buildings in general tend to be more efficient can be an explanation for this decrease.

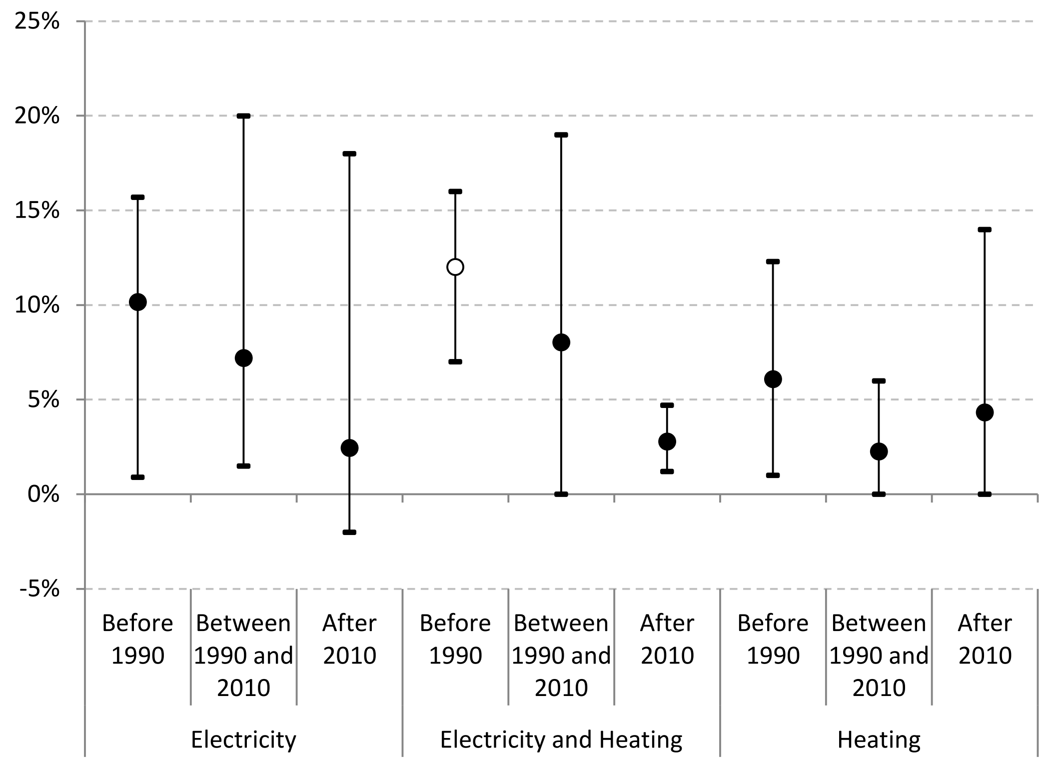


Figure 7: Maximum, minimum and average savings per consumption type and the period of the study. White average bullets refer to dataset composed by few studies (i.e. ≤3).

4.4 Savings per feedback type and medium

About media, this analysis reveals that the maximum saving is achieved with a continuous (direct) feedback provided by an In-House-Display (IHD) and that the indirect feedbacks provided with card (e.g. door hanger or other card/sign provided to the household by the researchers) are more effective than those provided by other means (excluding mixed modes). The strategies using bills are certainly more replicable and can be extended to higher sample (see Figure 9) due to their lower specific costs, while their effect also seems to be smaller (4% in average and 10% maximum).

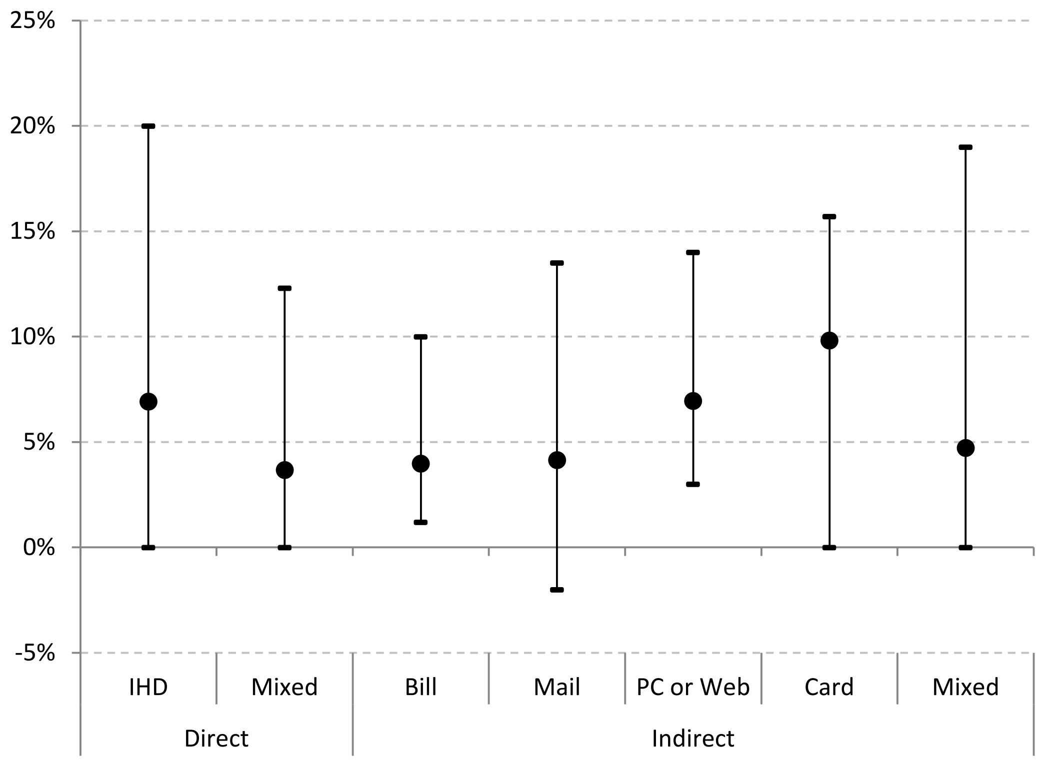


Figure 8: Maximum, minimum and average savings per feedback and medium type.

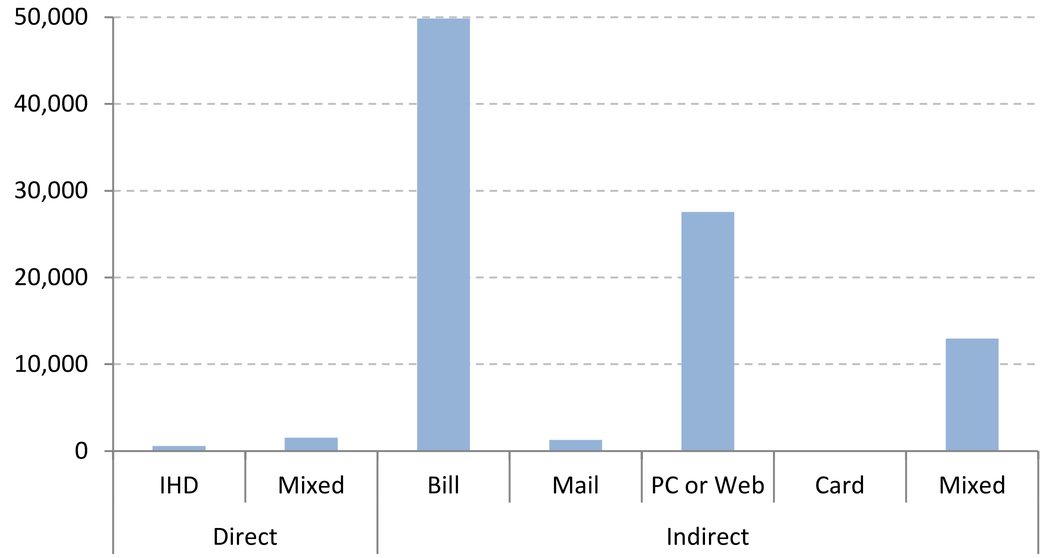


Figure 9: Average dimension of samples per feedback and medium type.

Looking forward, one could consider that the quantity of time spent interacting with computers and smart devices has considerably increased in the past years. So in the future, computerised and interactive feedback will have more opportunities to engage users for longer or more frequent periods of time. This suggests that digitised media may augment feedback effectiveness. A more specific discussion is needed on what type of technological medium can/should be chosen over another, since the interactivity may change a lot depending on the type of medium, the customer segment and many other variables such as the detailed design and usability of any, software, hardware or written material involved. For instance, if you have an IHD needing an active prompting action as your only mean to get feedback versus a push notification from a smartphone that warns you during different energy consumption moments and may guide on how to proceed in order to potentiate energy savings.

4.5 Savings per feedback type and frequency of interaction

Theory suggests that frequent feedback is more effective than infrequent feedback (because it helps link actions with consequences) and this is generally verified looking at the Figure below. The average savings obtained with indirect feedbacks are proportional with frequency and the absolute maximum saving has been observed with a continuous feedback provided by IHD. In accordance with previous studies, immediate feedback (the occupant is able to refer to the feedback directly after taking action) is particularly effective during a learning phase, when the user's attention is focused on specific action goals.

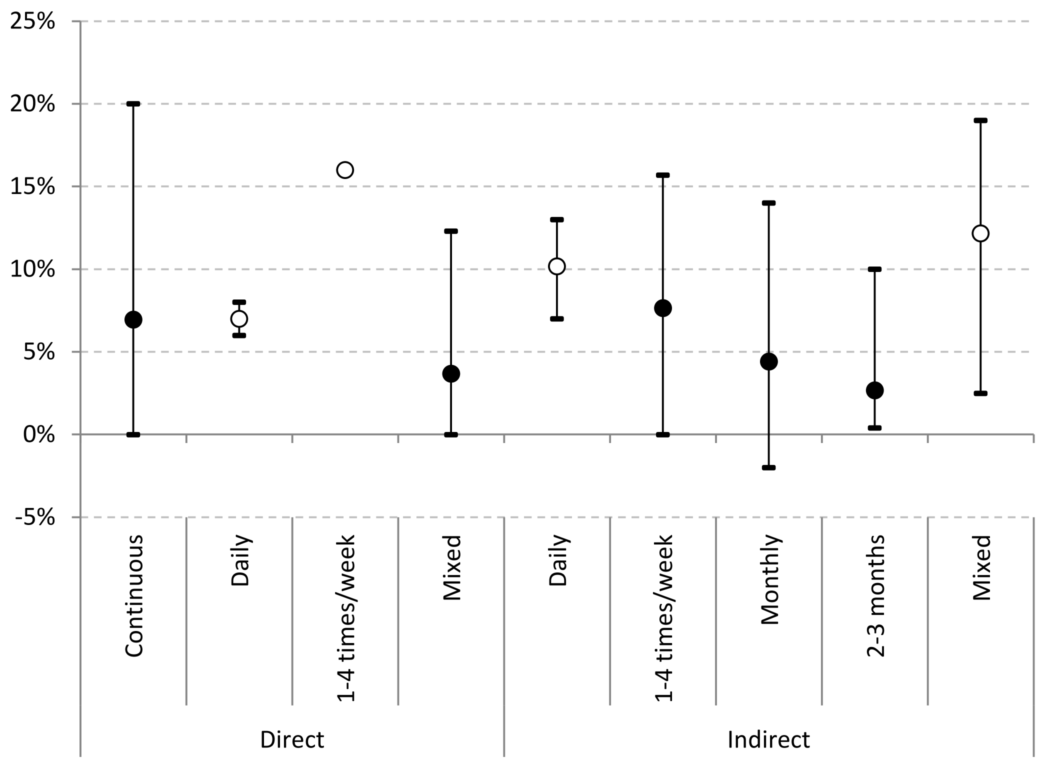


Figure 10: Maximum, minimum and average savings per feedback type and frequency of interaction. White average bullets refer to dataset composed by few studies (i.e. ≤3).

4.6 Savings per feedback type and duration of the study

Another variable influencing the effectiveness of a feedback is the duration over which feedback is provided. Over time, occupants' attention may shift as they move from initial task learning to the satisfation of a usual goal. Thus, the duration over which feedback is provided may impact how the feedback message is interpreted and where the users' attention is subsequently directed.

Data shown in Figure 11 suggests that the average energy savings decrease with increasing duration, both for direct and indirect feedback.

The fact that for short-term studies are achieving larger energy savings may be explained to a natural consumer engagement from the interest gained in the beginning of the studies, which may fade away further down the time.

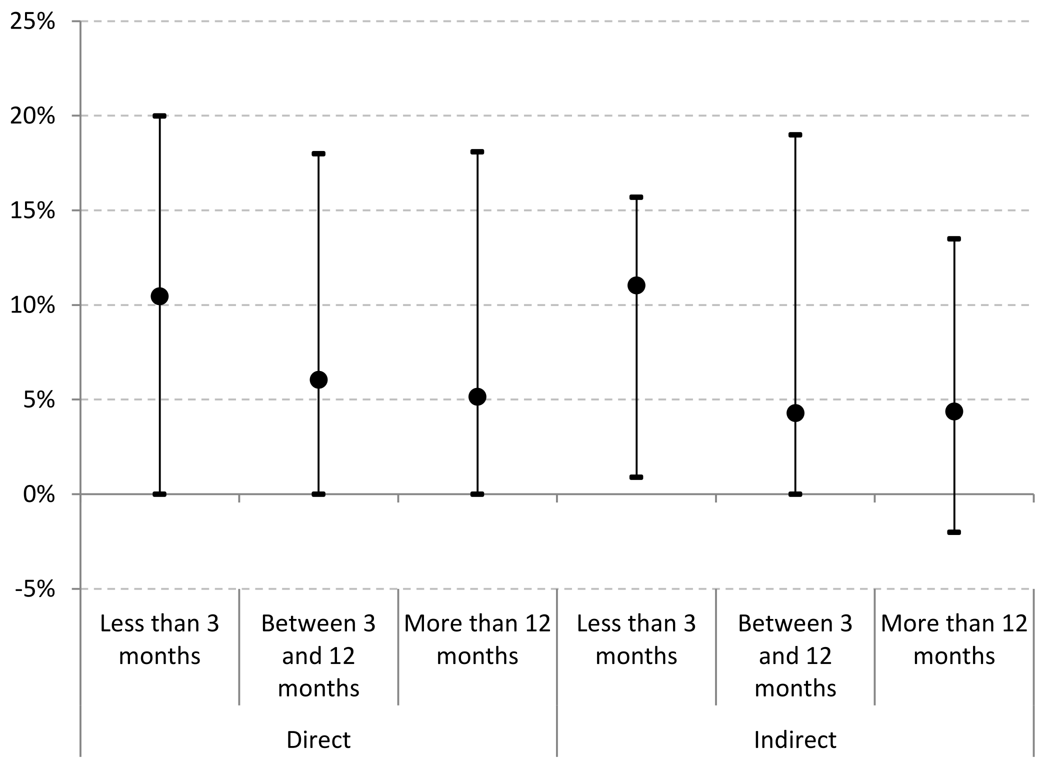


Figure 11: Maximum, minimum and average savings per feedback type and duration of the study.

5. Conclusions and Discussion

By evaluating the EU Member States NEEAPs some considerations may be:

- the roll-out of Smart Meters may allow for accurate and up to date energy data, but there is still a long way to go before it becomes a reality in all EU Member States. Real time and direct feedback is necessary to harness the full energy savings potential of such smart meters;
- requirements on individual consumers measurements exist in practically all EU-28;
- minimum requirements for billing exist in the majority of Member States;
- the frequency of readings and billing still needs to be looked into with further attention by the responsible entities. Readings once a year can be considered too little and lacking ambition considering the potential savings.

In general, the literature finds that feedback can reduce the households' energy consumption up to realistic 5 to 10% and that it works best when it is:

- tailored to the householder;
- presented clearly and engagingly;
- accompanied by advice for reducing energy consumptions;
- delivered regularly and with high frequency;
- made through enhanced billing versus standard billing;
- in the presence of In Home Devices, Web Based, interactive and digital;
- capable of providing information by appliance (even if cases are still rare);
- associated with a well-defined and challenging goal.

However, there are relevant uncertainties from the literature and significant gaps still remain in our knowledge of the effectiveness and cost benefit of feedback. In particular:

- the effect of feedback on consumers in different social and demographic groups;
- the effect of feedback on appliance purchasing decisions;
- whether feedback continues to work over time or whether it needs to be renewed/reshaped to keep householders engaged and maintain any conservation effects.
- the ability for feedback to facilitate the sharing of energy information between households, friends or neighbours is almost entirely unexplored;

- the divergence of cost-benefit calculations for feedback with advanced metering infrastructure needs to be explored as does the conditions under which the costs of feedback outweigh the benefits.

Although awareness of energy consumption has been increasing throughout the years, proactive actions towards final energy consumers' awareness of their energy consumptions and actions on how to improve their energy efficiency present themselves as a potentially effective way to reduce energy consumption.

It is important that the engagement of the final energy consumers is sustained in order to minimize the novelty aspect of a new way of energy feedback fading away after some time. Two-way communication from the energy provider and final energy consumers is recommended. Gamification tools like the comparison with similar energy consumers or the sense of gratification when the consumer's energy performance improves and is communicated towards the final consumer may pose as a good solution for the continuous engagement of consumers.

The frequency of the feedback moments is another crucial point in terms of the continuous engagement of final energy consumers. While too many feedback moments may become somewhat of a nuisance for the final energy consumers, a balance between too many and too few feedback moments should be studied and considered.

With the evidence, from the evaluated studies, that a bigger frequency of feedback leads to greater energy savings, it may be considered that the consumption readings (at least once a year) and the billing info (twice a year) required in the EED provisions may be increased for the sake of enhancing energy savings. The possibility for reducing the periodicity of feedback moments, not only in the periods respecting to the payment of the bill, but other dedicated moments throughout of the year, could also be looked into, since it has been shown that dedicated feedback leads to a bigger consumer engagement and consequently bigger energy savings.

Although the full smart meter roll-out in Europe is as yet a reality in only a few EU countries, the potentialities that such an infrastructure may arise, in terms of efficiency both for the demand as for the supply side, suggests that an even greater boost should be given to the implementation of smart meters European wide. The results of the meta-studies analysis is a clear proof of this, with the direct feedback through In-House Displays presenting the bigger savings.

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ANNEX I

Summaries of DG ENERGY/Joint Research Centre's workshop presentations on "Provision of consumption information to final customers - EC support to the Implementation of EED Article 10 in relation to billing information" taken place on the 21st of January 2016.

I.1 Informative billing and energy consumption – *Sarah Darby, University of Oxford, UK*

Three reasons for improving feedback

- Educational – without feedback, nobody learns. Everyone needs it, from customers to policymakers, designers and regulators.
- Economic – need well-informed energy users for effective markets.
- Cognitive / awareness – a lot of energy flows 'invisibly' in pipes, radiators, appliances etc.

Informative billing is one form of energy feedback and belongs within quite a complex 'information environment', within and beyond the home. Customers know something about what their home is like, the number and type of appliances and lights, heating system and household activities. The supplier can supplement this with detailed information about their energy consumption and about weather conditions (i.e., offering adjustments to heating consumption if appropriate).

Billing feedback (historic or comparative) in large-scale trials or programmes such as OPower, has typically led to durable savings of 2-3% compared with control groups with no such feedback.

Online feedback typically ineffective (relies on customer 'opting in'). Very little information to date on effectiveness of phone apps. Should not see online/apps as alternatives to billing feedback or to IHDs: they all act in different ways and in different contexts. Best seen as complementary.

'More is more'. Multiple feedback/information modes have more effect on demand than just one. Billing feedback typically more effective if combined with feedback from an in-home display (IHD) and/or advice and/or an educational programme and/or time-of-use price signals. As the report from the Irish smart meter trials noted, '*Results come from a combination of technology, price signal and customer engagement'.* (Engagement included bimonthly energy reports and IHDs.)

Early learning from GB smart meter rollout (where all householders are offered an IHD and installers are trained to explain them), shows that

- Effective residential smart metering involves installing a new piece of equipment AND enabling users to understand and use it. Smart metering enables demand reduction and demand response IF there is good feedback.
- Useful synergies between feedback from informative bills, IHDs, energy reports, energy advice (e.g. from housing association, local authority) and energy efficiency programmes.
- After 2-3 years of installations, there were measured reductions of 2.3% in electricity and 1.5% in gas compared with traditionally-metered customers. Scope to improve as everyone involved learns from experience.
- ~60% of the 2000 smart-metered customers interviewed were still using their IHDs between 6 months and >2 years after installation.
- Householders who made IHDs part of the household and used them to check on trends and exceptions in their energy consumption over time (a 'monitoring approach') were more likely to be experiencing benefits, including savings, than those who just used them to check real-time demand of appliances and who tended to lose interest after a few weeks. Need to encourage 'monitoring approach' in installer explanations, advisory material and follow-up support.

(https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/407568/8_Synthesis_FINAL_25feb15.pdf).

I.2 The question of energy reduction: The problems with feedback - *Kathryn Buchanan, University of Essex, UK*

Aim of presentation: to outline some of the problems that I believe are associated with giving feedback to householders about their energy use via an in-home display (IHD). While focusing on the negative side of feedback, this does not mean I am not "anti-feedback". In fact, I recognise that it can have real and tangible benefits such as increased awareness, knowledge of energy-related issues, and can prompt people to engage in energy saving actions. However, through pinpointing the problems associated with feedback we can reframe them as challenges, so that we can start to move towards identifying solutions to maximize the effectiveness of feedback-related initiatives.

Observation: Variation in estimates the exact amount of savings that can be achieved via feedback. Three reasons for this variation.

1. Differences between study in terms of key variables, namely, length of trial, target population, frequency, type and quality of feedback employed.
2. Differences in methodological rigour.
3. Feedback cannot reduce energy use by itself rather it depends on and requires human action and interaction (referred to as "the human factor").

Challenges associated with the "human factor":

- Lack of interest from some consumers' pre and post-acquisition. Only those interested may engage with the IHD. Novelty of IHD may wear off over time.
- Financial motivations – Small financial savings may undermine willingness to engage in energy saving actions or may appeal to those who are already using less than But what level of monetary savings are required to motivate behaviour change? Also, can realising the cost of energy-practises legitimize them?
- Comprehension –consumers sometimes do not understand their IHD; consumers that are more highly educated reported being more likely to use their IHD to save energy than those less well-educated; IHD do not explicitly link each energy-use activity in the home to cost, instead onus is on household to figure it out and they do not always get it right.
- Evaluation – how do people decide whether their energy use is good or bad? Evaluation is key because it precedes action. Some IHD include features designed to guide evaluative process, but do these always act in the desired ways? Possibility for rebound effects where any energy savings are re-invested into further energy consumption.
- Individual Differences – can a one-size fits all approach really be justified? Danger of reeling in those who are already "energy-engaged" with more information provided via IHD, rather than drawing in the "non-energy-engaged" who may have more scope for reduction.
- Action Potentials – energy saving actions are limited by people's circumstances (e.g., if renting than may be the landlords prerogative to install insulation but

not really any governmental policy that incentivizes this) and perceptions of "essential" energy use.

Recognise that the success of feedback depends on user-engagement or the 'human factor'. We should strive for 'smarter design' that keeps the "Human Factor" in mind.

Beyond IHD design, also needed are: fun, informative, and engaging marketing campaigns, customer support for the IHD from pre to post-acquisition and policy that supports householders in energy efficiency.

I.3 Observation, Experimentation, and Notification: Energy feedback as a means of engaging customers and reducing/shifting consumption - *Karen* Ehrhardt-*Martinez*, Navigant, US

Research indicates the energy feedback can help households to pay more attention to their energy consumption and to take actions to reduce energy demand. Feedback triggers attention and action by making energy more visible and meaningful. Different types of feedback appear to elicit different levels of energy savings and different sets of actions on the part of households. Households are inspired to act in response to a variety of factors and economic concerns appear to be less important than most policymakers tend to believe. Some evidence suggests that households may not have to pay attention to feedback consistently in order to benefit.

Invisibility of Energy and Ability to Observe Consumption. Modern energy systems provide households with convenient but largely invisible sources of energy for heating, cooling, lighting, cooking and a variety of other end uses. However the shift from wood, coal, and candles to modern energy sources has created a rift between people and the energy that they consume, making it highly difficult for people to monitor or manage their energy consumption. Instead electricity and natural gas flow invisibly into our homes and modern energy units (kwh or therms) hold little meaning for most people. As a result, most people don't know how much energy their household consumes and when they do, they often don't know which end uses are responsible for the majority of that consumption, whether their level of consumption is reasonable or unreasonable, or where they should target efforts to reduce consumption. Feedback creates an opportunity to make energy more visible, enhance people's knowledge and understanding of their energy consumption patterns and ways to save energy, and give meaning to modern energy measures of consumption.

Triggering of Experimentation, Actions and Savings. A wide variety of research studies clearly indicate that feedback is effective at generating energy savings, and a growing number of studies are painting a clearer picture as to the actions that households are taking in order to generate those savings. This research suggests that different types of feedback generate different types of actions and different levels of savings. Indirect forms of feedback such as home energy reports and daily or weekly feedback (often provided online via a web portal) tend to generate household level savings between 3.5 and 8.5% while direct forms of feedback provided in real time or near real time by smart meters and in-home displays or mobile devices, tend to generate savings of 9 to 12%. Some research suggests that indirect feedback may be better for generating changes in energy consumption from large end use demands such as space heating and cooling while direct feedback may be better at changing demand associated with smaller end uses such as plug loads and devices. Expert advice continues to play a critical role in guiding energy savings associated with indirect feedback and large end use demands, whereas direct sources of feedback tend to generate savings via in-home experimentation. Evidence from a recent study that looked at self-reported behaviors across three types of feedback (enhanced billing, online, and real-time displays) suggests that feedback is much more likely to induce behavior-based approaches rather for reducing energy consumption (as opposed to investments in more energy efficient equipment) regardless of the type of feedback provided. Despite the predominant focus on behavior, households with enhanced billing were more likely to focus on turning things off and using alternative technologies (CFLs versus incandescent bulbs for example). Households who received online feedback were more likely to focus on conservation behaviors (washing and drying full loads of laundry or air drying laundry, for example) and also embraced alternative technologies. Households who received real-time feedback tended to have the most varied energy saving strategies but were more included to focus on conservation settings (on appliances), enhanced control mechanisms like timers and smart strips, and maintenance activities.

Evolving Use of Notifications (and other means) to Inspire Attention and Action. While feedback is a great way to provide households with useful energy information and to frame that information in a way that provides meaning, household energy feedback may not be effective and getting all households to pay attention to their consumption patterns and levels or to hold the attention of households for long. We need to move beyond the three underlying myths that 1) people will act rationally and do things that are in their best interests, 2) economics are always the best means of motivating action, and 3) people need to continuously pay attention to feedback in order for it to be effective. Social science research provides valuable insights that suggest that people often act in ways that are best described as predictably irrational, that the benefits of economic incentives are often short lived and sometimes counter-productive, and that people aren't always aware of what will motivate them to action. Finally, a growing field of research has begun to assess whether households need to consistently monitor feedback in order for it to be effective. Instead of the need for regular monitoring, these approaches are increasingly looking to models that leverage seasonal changes, life events and notifications associated with energy usage thresholds as a means of encouraging attention to energy issues in those instances when such attention is most warranted.

Policy Take Aways. Feedback has proven to be an effective approach for reducing energy consumption because it makes energy more visible and meaningful to households. Different types of feedback tend to generate different types of action and different levels of savings and these factors should be taken into consideration when developing a strategy for providing feedback. The effects of feedback can be enhanced through a variety of strategies that motivate households to take action. While economic incentives may play a role in motivating action, their effects can be short lived and may even be counterproductive. It is important to look to other means – such as social norms, opt out strategies, and public commitments – for motivating household engagement and action. Finally, temporal strategies may also play an important role in encouraging households to pay attention to their energy consumption at those key moments that matter most, thereby avoiding attention fatigue. Taken together, these approaches can help maximize the energy savings from household energy feedback.

I.4. Empowering Customers to Save Energy by informative Billing: The Empowering Project - *Stoyan Danov, CIMNE, Spain*

The project develops and implements a range of services and software tools aiming at empowering the energy utilities' customers and helping them to save energy on a basis of information they receive on their energy bills or through online tools.

The services are developed in two iterations and then implemented over a population of more than 344.000 consumers. The service effectiveness is evaluated in terms of energy savings, user acceptance and satisfaction. The legal, technical and organisational factors influencing the successful implementation at the utilities are analysed.

The project achieves measurable savings within the action and provides an open source software infrastructure, guidelines and dissemination for widespread service application and durable impact after the action.

Results of the project:

- Powerful open source solution for big data analytics and a portfolio of billing information services adapted to the European market and data protection legislation.
- Implementation and testing in 4 utility pilots in Austria, France, Italy and Spain
- Considerable interest in the solution due to the flexibility and the utility-tailored implementation approach: Two additional utilities adopted the services within the execution phase of the project and more than 20 utilities expressing interest in adopting the Empowering solution in the next years.
- Energy savings up to 15% achieved among the users in 3 of the 4 pilots during the first 6 months of pilot operation

Lessons learnt & Recommendations:

<u>Regulation for improved consumption information:</u>

- Clear and unified procedures for metering data exchange between DSO and energy retailer are necessary to assure data availability soon after consumption is produced. Retailers are more interested in offering services to their customers.
- Considering certain billing information services as end-user energy saving actions of the energy suppliers will incentivise their widespread adoption

<u>Considerations for technical implementation at utilities:</u>

- Billing information services should be ideally integrated with the billing IT systems at the utilities and should use verified consumption data in order to inspire confidence.

- Customers should have an easy access to the services through multiple channels.
- Offering services to the whole customer population (opt-out) is more effective than searching pro-active registration by customers (opt-in). From the tested solutions, the combination of Energy Report and Online Self-assessment Tools proved more effective than each of the solutions offered separately.

Organisational aspects for implementation:

- The successful implementation at the utilities requires the creation of cross-department team involving Marketing, IT and Customer Service staff, and continuous support by the general management.
- Presentation of the services to the customers should be done once they are technically operational to avoid false expectations. Customer engagement is a key for success.

I.5 Provision of historical consumption data to drive energy efficiency - *Giulia Gioffreda, Opower, UK*

Behavioural energy efficiency programmes are built on a single powerful idea: that providing people with better information about their energy use motivates them to use less. It's a premise pioneered by social science and proven by years of rigorous testing. When utility customers start receiving proactive, personalized insights into reducing their energy waste, they pay attention and start changing their behavior. That, in turn, transforms them into a clean energy resource. Engaged utility customers use less electricity than their peers, generate fewer carbon emissions, and ease demand on the grid. They also save money on their bills and think more highly of their energy providers.

There are 5 principles that we always follow at Opower when helping utilities to improve their communication with consumers:

1. Design for how people actually behave
2. Assume people don't care
3. Always lead to action
4. Aim for lasting relationships
5. Build for everyone who receives a utility bill

Those 5 principles are always combined with behavioural science techniques, such as the use of neighbor comparison; social norms; loss aversion principle; reciprocity principle; setting an EE goal; use a format of communication designed for limited attention span (etc.).

Most of the times the problem isn't the quantity of the content. It's the quality. Many utilities are falling back on messaging that's generic, redundant, and fails to provide much value. And all too often, their BEE programs are following suit. To capture customers' attention and achieve long-term energy savings, utilities need to talk to their customers as individuals, sharing highly personalized content that mirrors their own experiences and preferences. Timing is also critical. A 2012 study from Accenture found that customers spend just 9 minutes a year engaging with their energy providers. It's imperative that utilities increase the moments to engage their customers. Billing information should reach consumers at least monthly.

Behavioural energy efficiency should always be scientifically measured. A high level of measurement rigor is achieved through careful experimental design, and specifically by implementing randomised control trials. A randomised controlled trial (RCT) is a specific type of scientific experiment and is the gold standard for clinical trials. In such trials, RCTs are often used to test the efficacy or effectiveness of various types of medical interventions within a patient population. RCTs may also provide an opportunity to gather useful information about adverse effects, such as drug reactions. RCTs have also been recognized as the gold standards to evaluate behavioural energy efficiency.[2]

I.6 Consumer Organisation perspective - *Gillian Cooper, Citizen Advice, UK*

Our predecessor body, energywatch, made a super-complaint about energy billing in 2005. Energywatch believed that poor quality bills and billing processes created a barrier to:

- enable consumers to make informed decisions about their level of usage, budget for their usage or understand the value of switching to another supplier;
- effective competition in the energy market, with customers retained by obfuscation of essential data; and
- the take up of energy efficiency measures

Since the super-complaint, there have been a number of changes made to energy bills

- Information requirements changed as a result of Ofgem's Energy Probe (2008-2009) and Retail Market Review (2010-2013) as well as the transposition of European Directives: all were intended to boost market participation

[2] Evaluation, Measurement, and Verification (EM&V) of Residential Behavior Based Energy Efficiency Programs: Issues and Recommendations, SEE Action Network, May 2012.

- Individual changes - tariff name, annual consumption, translation of kWh to services - all well-intentioned, but
- Taken together, these changes mean bills are longer and more complex

Research conducted by Citizens Advice in 2014-15 show that while the majority of consumers are satisfied that they understand their energy bills, they are more likely to have problems with:

- Understanding the cost per unit
- Understanding how much energy has been used and/or whether there an opportunity to save money by reducing energy use or switching supplier

What Citizens Advice thinks needs to happen next with energy bills:

- Rollout of smart meters will improve accuracy of historical billing information
- BUT consumers will need help with behaviour change
- Regulatory requirements are an opportunity and a challenge when it comes to improving energy bills
- Key information on bills must be provided in a comparable format
- Bill content and presentation must reflect consumers' preferences and greater differentiation is needed between bills and annual statements
- Must take into account the needs of different groups of consumers, as research shows active consumers react to lack of trust in suppliers by scrutinising company communications & bills and by switching supplier and inactive consumers react by becoming more inactive
- Introduce improved protections for consumers from inaccurate bills to ensure the smart meter rollout delivers consumer benefits

What Citizens Advice is doing:

- Providing advice, help and practical tools to inform and educate energy consumers
- Carrying out research looking at alternative ways to engage energy consumers

I.7 The regulator perspective - *Marielle Liikanen , CEER*

CEER believes that the current provisions from the Energy efficiency directive are not sufficiently applied, implemented, and/or upheld to guarantee easily accessible, sufficiently frequent, detailed and understandable information on consumers' energy intake. Closer coordination between sector specific regulators and consumer authorities is needed to achieve the goals of the EED. New developments e.g. smart metering will also lead to improvements in the information provided to consumers and how it is presented

I.8 The consumer perspective - *Zoe Mcleod, OnTheRecord, UK*

OnTheRecord is a new social enterprise. Our mission is to make businesses better so as to save customers time and money. We have a particular focus on improving accessibility to services, especially for customers with disabilities.

<u>Consumer benefits</u>

It is important that any regulation on billing and energy information is focused on the desired consumer outcomes. From a consumer perspective the key benefits are:

- **Energy reduction and shifting** – to help customers reduce costs and carbon. Consumers may interpret information and use this to take action themselves, with the help of a third party, or via automation, particularly in the future.
- **Money management** – information facilitates greater control over energy spending, enables consumers to check if bills are accurate and budget more easily. In turn this helps to build trust in companies. Control is also a key component of affordability.
- **Improving purchasing decisions** – with the right information in the right format, customers can be incentivized to make purchasing decisions and are better informed when they do. E.g. they can more easily identify the best energy deal for them, or calculate if an energy efficiency product will give them benefits and its payback time.

Balancing prescription with more outcomes based approaches

There is an important role for prescription in regulation in this area but care must be taken as to how and when it is applied. Current rules have led to unintended outcomes for consumers e.g. longer more complex bills.

It is recognized that information alone, while a prerequisite, is rarely enough to deliver behavior change and outcomes outlined above. The evidence base in terms of what 'works best', particularly around feedback mechanisms, such as in home displays versus mobile phone apps etc. is still largely inconclusive, particularly in the case of gas. A one-sized fits all approach to providing information is however recognized as not the best approach to deliver the impact needed. Evidence indicates that some consumers in more vulnerable situations also need additional support or tailored approaches. For all these reasons it is important for much of the regulation in this space to allow for innovation. Focusing on what Member States must deliver by way of consumer outcomes (that is ensuring access to information to enable switching, energy reduction, purchasing decisions) rather than how they must do (put predefined information on bills) allows for flexibility to respond to market circumstances, as well as a better degree of future proofing. However, in order for this to work there must be appropriate monitoring and reporting of the impacts/outcomes.

Prescription is best applied where there is evidence that the current market and wider structures have historically failed to, and/or are therefore unlikely to deliver the necessary consumer outcomes e.g. there is evidence base of problems, or there are insufficient commercial incentives for the market players to take action. Also, where a standardized approach is necessary to ensure interoperability. This is especially important in a smart world with the likely growth in bundling of services across energy, telecommunications, transport and other sectors. We therefore make the following recommendations.

Recommendations:

1. **Establish an inclusivity principle** – a significant number of consumers face barriers when accessing information due to their personal characteristics or their circumstances. E.g. if they don't use or have internet access they will need hard copy information; customers with dexterity problems can find it hard to use touch screen energy displays; those who are blind or partially sighted need tailored communications etc. Companies should take all reasonable steps to ensure that services are inclusively designed and that they meet the needs of all consumers. There are already: precedents for this in some Member States; a sound business case for inclusive approaches; and good practice standards to facilitate

compliance.

2. **Further improve access to the granularity of time of use of consumption data** – this is critical for customers to make informed switching decisions in particular.

    i) Companies should make energy consumption information available in sufficient detail that allows customers or their representatives to identify the best offers for them. This doesn't currently happen. e.g. in GB how much energy a customer needs to use off-peak to benefit from a time of use deal varies from 9%-55% depending on the tariff. Customers need to know how much energy they consume each hour to calculate if they are better or worse off on different deals. They don't have the information to do this. This is particularly important to establish given the likely growth in demand side response and 'smart tariffs'.

    ii) There should be a fairness principle that whatever granularity of data companies 'take' should be easily available to consumers for free. E.g. if companies are accessing half hourly data, this should also be available to the customer for free.

3. **Require greater standardization of data to allow for timely data portability –** e.g. in terms of terminology, format. This is to enable data sharing with third parties who can help deliver the outcomes outlined, or for the customer to use with tools such as automation. Combining data sets can also bring additional value. The slowness with which suppliers have participated in the GB Midata project indicates that there are often insufficient commercial incentives for companies to give appropriate access to data. Indeed generally companies are reluctant to share this 'black gold'.

4. **Explore requiring access to new kinds of smart metering data** - e.g. the data that prosumers need, and the availability of data about quality of supply, such as about outages, and voltage quality. This could help customers seek compensation and drive improvements in service. There is little incentive on companies to provide this, especially when they are liable if service is found to be substandard.

5. **Introduce new regulation on billing accuracy –** billing problems are the largest source of consumer complaints in GB. Smart metering is expected to significantly improve billing accuracy but it will not resolve all problems. Customers have a low tolerance for estimated bills, particularly with smart meters, and accurate bills are a top priority. A particular problem is back-bills when customers are sent a catch-up bill for monies outstanding, due to a supplier error – these can run into the hundreds and thousands of pounds. Back-bills can cause considerable detriment, pushing customers into debt and onto more expensive payment methods. Regulation is necessary to ensure the liability for billing problems does not rest with the consumer and to improve billing accuracy. There are precedents for this in a number of countries. This is key to building consumer trust and engagement.

I.9 The Utilities point of view - *Sébastien Dolige, Eurelectric*

In a competitive market, bill design should be left to retailers to diversify their brand and image, and meet their customers' needs. This is one of main recommendations of the EC WG report on E-billing to the London Forum (2013)

In most EU countries suppliers are in constant dialogue with consumers (e.g. consumer panels) and energy companies are taking steps to make energy bills clearer and offers easier to compare, such as by reducing their number and simplifying their structure. See for instance a recent initiative by SSE:

http://sse.com/newsandviews/allarticles/2016/02/new-sse-bill-design-aims-to-end-energy-bill-confusion/

As constantly advocated by EURELECTRIC, improved transparency in price and offers is also linked to better - which sometimes mean less - regulation. In several EU member states, bills are heavily regulated and, whilst many consumers complain that there is too much information on their bills, making them difficult to read, suppliers are not always allowed to simplify them. In France for instance, more than 70% of the bill is fully regulated.

In our view before coming up with more regulation, policy-makers should assess the impact of current national legislative provisions and requirements regulating the presentation of offers and bills. We think there would be merit in encouraging more evidence and principle-based regulation rather than dictating how things should be done.

Policy makers should also consider that many other options exist to provide information to consumers. New communication technologies - display devices or individual feedback services on the internet or telephone - are changing the way suppliers and ESCOs communicate with their customers and will play a greater role in monitoring or optimising customers' energy consumption.

Smart meters with appropriate functionalities and the availability of real-time metering data are of utmost importance to provide innovative services to customers. SM are sometimes taken for granted but they are not there yet in most Member States. The Commission should therefore keep a watching brief on member states' roll-out plans and smart meters functionalities.

Finally as shown by EURELECTRIC's recently published infographics 'Making sense of your electricity bill', the average EU household electricity bill in 2014 was made up of 37% of energy and supply costs, 26% of network costs and 36% of taxes and policy costs. What is particularly disconcerting is that as from 2014 European households pay as much for electricity as for taxes and policy costs. As the power sector makes strides towards sustainability and electricity becomes decarbonised, its role as Europe's fuel of choice is jeopardised because of the burden put by governments on its final price. It is all the more urgent that European policymakers rethink how costs are levied on everyone's bill if Europe is to reach decarbonisation at the lowest possible cost to all consumers

I.10 State of play on implementation of Article 10 in Finland, *Leino Sirpa*

Smart Meter roll-out in Finland

- Electricity - Legal framework
  - Almost 100 % coverage of smart metering
- District heating - Commercial basis
  - 80 % of meters register hourly data,
  - 90 % are remotely read

Metering Legal Framework - Requirements for metering (electricity):

- ✓ remote reading daily

        - ✓ shall register over 3 minute black-out time
        - ✓ remote demand response feature (1 relay)
        - ✓ data storage in DSO systems
        - ✓ security of data (meters and systems)
- Customers have access to their hourly measurements via online service by DSO
- Standard open interface at the meter for real time consumption data has to be provided on customer request

Several benefits to the market actors and the whole energy system:

- Customer
    - Customers have been switched from billing based on estimated to billing based on actual consumption. Experiences:
        - *Bills are easier to understand.*
        - *The questions have before been about not understanding the bill, now they are about how the customer could save energy.*
        - *Some customers have started to use energy more efficiently. This is also because of real time feedback information about consumption to the customers*
    - Wide variety services how to deliver hourly data to the customers via on-line systems (web, smart phone, tablet) and helping customers better understand their energy consumption
- Energy system benefits
    - Possibility to involve also small customers in to demand response and thus the ability to integrate volatile renewables
    - Electricity market functions close to real time – from big production to small customers
- Supplier benefits
    - Possibility for variety of new pricing methods and other new business possibilities
    - Billing based on actual consumption improves business planning and cash management (increased predictability)
- Third parties / ESCOs
    - New innovative business possibilities

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